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AN OPTICAL TRANSMISSION BODY

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[*There are no amendments to this patent.*]

(54) [Title of the invention]

An optical transmission body

(57) [Abstract]

[Constitution] An optical transmission member consisting of a transparent core and a transparent cladding material having a refractive index lower than the core material, for which light enters from one end of the above-mentioned core material and the incident light is transmitted toward the other end, and a continuous or discontinuous fine roughness consisting of projecting stripes and recessed grooves inclined parallel to the direction of travel of the light are formed over a part or the entire surface in the travel direction of travel of the light at the boundary between the cladding material and the core material from the light entrance end to the exit end.

[Effect] According to the present invention, it is possible to produce an optical transmission member having a uniform, high surface luminance over the entire length while securing transmission of light that can be used safely even in an environments such as underwater, etc.

[Explanation of codes]

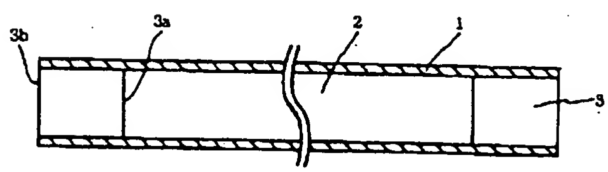
1 Cladding material

2 Core material

3 Stopper

3a End face

3b End face



[Claims of the invention]

[Claim 1] An optical transmission member consisting of a transparent core and a transparent cladding material having a refractive index lower than the core material, for which light enters from one end of the above-mentioned core material and the incident light is transmitted toward the other end, and a continuous or discontinuous fine roughness consisting of projecting stripes and recessed grooves inclined parallel to the direction of travel of the light are formed over a part or the entire surface in the travel direction of travel of the light at the boundary between the cladding material and the core material from the light entrance end to the exit end.

[Detailed explanation of the invention]

[0001]

[Field of industrial application] The present invention pertains to an optical transmission member with increased surface luminance at the peripheral surface of the optical transmission member.

[0002]

[Prior art and problems to be solved by the invention] As an historical illuminant with a long luminous body, the neon tube can be mentioned. However, neon tubes require approximately 1 kW of power per 1 meter or length, and a voltage corresponding to the length of the tube is required; thus, longer tubes require high voltages; thus, in general, the length is limited to approximately 3 to 5 meters. Furthermore, due to the short circuit potential, it is not possible for them to be used in water; furthermore, since neon tubes are made of glass, breakage of the glass tube poses a problem; furthermore, glass blowing is required to bend the tube; thus, a certain degree of skill is required.

[0003] In an attempt to eliminate the above-mentioned problems, optical transmission tubes that can be used at lengths of 50 m produced by injecting a transparent core solution to a flexible tube (product of Bridgestone Corp.), plastic optical fibers (product of Mitsubishi Rayon Corp.), etc. have been suggested. The above-mentioned optical transmission tubes can be used in water or an environment where explosion is a possibility. Furthermore, the complex process of glass blowing required for production is not necessary, and handling is easy; but the luminous brightness is approximately 1/2 to 1/4 of the neon tube.

[0004] Furthermore, as an optical transmission tube with a high luminance, an optical transmission tube with a core material made of a phosphate type solution is suggested by the applicant in Japanese Patent Application No. 4-26668. In the above-mentioned optical transmission tube, a small amount of ester type plasticizer is mixed with the phosphate solution, and the luminance of the peripheral surface can be increased to approximately 5 times the luminance of the conventional optical transmission tube through changing the mixing ratio of the above-mentioned components. However, in the above-mentioned optical transmission tube, the color temperature is reduced with increasing length; thus, the light emitted is likely to become yellow, and non-uniform light emission is likely to occur along the length of the tube, in some cases.

[0005] Furthermore, a method in which the luminous intensity at the peripheral face of an optical fiber is increased by producing a rough surface on the plastic optical fiber with sandpaper, etc. has been disclosed; but formation of the rough surface is difficult, and repeatability of the process is poor; furthermore, an adequate degree of luminance can be achieved in the area near the light source, but the farther from the light source, the darker the fiber becomes; as a result, it has not been possible to produce a luminous body with a length of longer than approximately 1 m.

[0006] The present invention is based on the above-mentioned background, and the objective of the present invention is to produce an optical transmission member having a uniform, high surface luminance over the entire length while securing transmission of the light that can be safely used even in an environment such as underwater, etc.

[0007]

[Problems to be solved by the invention and effect] In an attempt to achieve the above-mentioned objective, the inventors carried out much research and as a result of their effort, discovered that high luminance can be achieved over the entire length when a transparent cladding material having a refractive index lower than the core material, for which light enters from one end of the above-mentioned core material and the incident light is transmitted toward the other end, and a continuous or discontinuous fine roughness consisting of projecting stripes and recessed grooves inclined parallel to the direction of travel of the light are formed over a part or the entire surface in the travel direction of travel of the light at the boundary between the cladding material and the core material from the light entrance end to the exit end. In other words, in a optical transmission member having a core-cladding structure, the light travels as the light undergoes total reflection at the interface between the core material and cladding material, but when high roughness with projecting stripes and recessed grooves in the direction perpendicular to the direction of travel of the light exist, the angle of incidence of the light becomes high, as a result, the light is transmitted through the cladding and emitted from the peripheral face, and when the fine roughness consisting of projecting stripes and recessed grooves do not exist along the light path, the incident angle in the travel direction of the light does not change, thus, the light is transmitted as total internal reflection occurs repeatedly. It was further discovered that the light with a high incidence angle is gradually transmitted through the cladding and out of the optical transmission member when roughness exists outside the course of the travel direction of the light. Based on the knowledge, it was discovered that light

transmittance along the length (light travel direction) can be achieved, and at the same time, a uniform light emission providing high peripheral surface luminance along the entire length can be achieved, and accomplished the present invention.

[0008] In the following, the present invention is explained in further detail. The optical transmission member of the present invention is made of a transparent core material and a cladding material with a lower refractive index than that of the core material, and the ray of light enters from one end of the above-mentioned core material and the incident light is transmitted toward the other end, a continuous or discontinuous fine ruggedness with parallel projecting stripes and recessed grooves shape inclined to the travel direction of the light and formed partially or wholly along the travel direction of the light at the boundary between the cladding material and core material from the entrance end to the exit end.

[0009] An example of optical transmission member of the present invention is shown in Fig. 1. In Fig. 1, 1 is the transparent cladding material, 2 is the transparent core material that fills the cladding material, and 3 is a stopper.

[0010] In this case, for the material used for the hollow tubular cladding material, a flexible material that can be molded to form a tubular shape and having a refractive index lower than that of the core material, for example, a plastic or elastomer, etc. can be used. For specific examples of the above-mentioned materials, polyethylene, polypropylene, polyamide, polystyrene, ABS, polymethyl methacrylate, polycarbonate, polyvinyl chloride, polyvinylidene chloride, polyvinyl acetate, polyethylene-vinyl acetate copolymer, polyvinyl alcohol, polyethylene-polyvinyl alcohol copolymer, fluorine resin, silicone resin, natural rubbers, polyisoprene rubber, polybutadiene rubber, styrene-butadiene copolymer, butyl

rubber, halogenated butyl rubber, chloroprene rubber, acrylic rubber, EPDM, acrylonitrile-butadiene copolymer, fluorine rubber, silicon rubber, etc. can be mentioned.

[0011] Among those listed above, silicone type polymers or fluorine type polymers with low refractive indexes are especially desirable, and in specific terms, silicone type polymers such as polydimethyl siloxane polymer, polymethyl phenyl siloxane polymer, and fluorosiloxane polymer, and polymers such as polytetrafluoroethylene (PTFE), tetrafluoroethylene-hexafluoropropylene copolymer (FEP), tetrafluoroethylene-perfluoroalkoxy ethylene copolymer (PFE), polychlorotrifluoroethylene (PCTFE), tetrafluoroethylene-ethylene copolymer (ETFE), polyvinylidene fluoride, polyvinyl fluoride, vinylidene fluoride-trifluorochloroethylene, vinylidene fluoride-propylene pentafluoride, vinylidene fluoride-propylene pentafluoride-tetrafluoroethylene three component copolymer, tetrafluoroethylene propylene rubber, fluorine type thermoplastic elastomers, etc. can be mentioned. The above-mentioned material can be used independently or a mixture of two different types of materials can be used in combination.

[0012] Furthermore, a gas such as air can be used for the cladding material, in which case, the optical transmission member is especially a structure consisting of a core material.

[0013] For the core material, a transparent solid, liquid, or fluid material having a refractive index higher than that of the cladding material can be used.

[0014] In this case, for the solid transparent material, an acrylic type resin and methacrylic type resin can be used effectively, and homopolymers and copolymers of alkyl acrylate and alkyl methacrylate such as methylacrylate and methylmethacrylate, other alkyl acrylate and alkyl methacrylate that are copolymerizable with the above-mentioned

monomers and capable of producing a transparent polymer can be mentioned.

[0015] Furthermore, for specific examples of liquid or fluid type transparent materials, inorganic salt solutions, polyhydric alcohols such as ethylene glycol and glycerol, silicone oils such as polydimethyl siloxane and polyphenylmethyl siloxane, polyether, polyester, hydrocarbons such as liquid paraffin, hydrocarbon halides such as trifluorochloroethylene oil, phosphates such as tris(chloroethyl)phosphate and trioctyl phosphate, and polymer solutions diluted with an appropriate solvent, etc. can be mentioned. The above-mentioned materials can be used independently or a mixture of two different types of materials can be used in combination.

[0016] Stopper 3 is used even when a solid material is used for the core material, but it is essential when a liquid or fluid material is used for the core material. In this case, when the stopper is used as a window material for the light, it is necessary for the material used to produce the stopper to be a transparent material, and for specific examples of the above-mentioned stopper, inorganic glasses such as quartz glass, polycomponent glass, saphire, and crystal, organic glasses and transparent plastic materials such as polyethylene, polypropylene, ABS resin, acrylonitrile, styrene copolymer resin, styrene-butadiene copolymer, acrylonitrile-styrene copolymer resin, acrylonitrile-EPDM-styrene three component copolymer, styrene-methyl methacrylate copolymer, methacrylic resin, epoxy resin, polymethyl pentene, allyl diglycidyl carbonate resin, spiran resin, amorphous polyolfine, polycarbonate polyamide, polyallylate, polysulfone, polyallyl sulfone, polyether sulfone, polyether imide, polyimide, polyethylene terephthalate, diallyl phthalate, fluorine resin, polyester carbonate, and silicon resin, can be mentioned. Among those listed above,

inorganic glasses such as quartz glass and pyrex glass, and polycomponent glass have excellent transparent high heat resistance, and high chemical stability, and furthermore, said materials do not react with the core material that comes in contact with end face 3a or glass or moisture that comes in contact with end face 3b; thus, long-term stability can be achieved.

[0017] Furthermore, when transparency is not required, metals and ceramics can be used as well.

[0018] In general, the optical transmission member of the present invention is formed into a tubular material with the outer diameter of the cladding material in the range of 3 to 110 mm, and a length of 1 to 100 m. Furthermore, the optical transmission member may be triangular in shape, or have a square rod shape, or be a sheet-form member.

[0019] In the optical transmission member of the present invention, a continuous or discontinuous fine roughness consisting of parallel projecting stripes and recessed grooves inclined to the direction of light travel and partially or wholly covering the travel direction of the light are formed on the boundary between the cladding material and core material from the entrance end d of light to the exit end e as shown in Fig. 2 and Fig. 3. The cross section shape of the above-mentioned fine roughness may be wedge-shaped, groove-shaped, or semi-spherical and two or more different shapes can be used in combination.

[0020] It is desirable for the mean roughness (Ra) of the fine roughness in the travel direction of the light to be low, and in the range of 0.01 to 10 μm is suitable, and in the range of 0.01 to 1 μm is especially desirable.

[0021] Furthermore, when a discontinuous fine roughness with projecting stripes and recessed grooves is used, the mean length is not especially limited, and a length in the range of 1 to 50 mm is suitable.

[0022] The above-mentioned fine roughness may be formed on either the core material or cladding material, but, in general, it is formed on the cladding material. However, when gas is used for the cladding material, it is formed on the core material.

[0023] When the above-mentioned fine ruggedness with projecting stripes and recessed grooves is formed on the inner surface of the tubular cladding material, the method described below can be used.

(1) Extrusion of cladding material is performed with a die orifice having the desired projecting stripes and recessed groove shape.

(2) Extrusion is performed for the cladding material to form a hollow tube with a smooth inner surface, and formation of the pattern is achieved as a result of the temperature difference between inside and outside the hollow tube during the cooling process. In this case, cooling is performed from the outside for the extruded material, thus, distortion occurs inside due to stress, and waves and cracks are formed inside the extruded material.

(3) A removable needle-like protrusions are formed on the die orifice on the inner side of the tube. In this case, the depth of the protrusions inserted are made variable by means of a piezo element; thus, the depth, distribution, and density of the pattern formed on the inner surface of the extruded hollow tube can be changed, and control of the luminance is made possible.

[0024] Furthermore, when a lower number of regions of fine roughness with projecting stripes and recessed groove shape are formed at or near the light source and a higher number of fine roughness regions with projecting stripes and recessed grooves are formed away from the light source, the uniformity of luminous in the light travel direction can be improved further.

[0025] The optical transmission member of the present invention produced as described above can be used effectively for optical transmission tubes having uniform luminosity in the length direction over the entire length, and can be used for backlighting of liquid crystal displays for computers, etc.

[0026]

[Application examples] In the following, the present invention is explained further with application examples and comparative examples but the present invention is not limited to these application examples.

[0027] [Application Example 1] Extrusion was performed for FEP to produce a thickness of 0.5 mm and a tube with an inner diameter of 12 mm and an outer diameter of 13 mm (length of 10 m) was produced. The mean roughness (Ra) on the inner surface in the light travel direction was 0.70 μm, and the Ra in the peripheral direction was 7 μm, and the mean length of the groove was approximately 5 mm.

[0028] Trioctyl phosphate was used as a core material to fill the above-mentioned FEP tube, and both ends were closed with a quartz rod to produce an optical transmission tube.

[0029] [Application Example 2] In Application Example 1 above, an Ra in the peripheral direction of the FEP tube of 1.5 μm was used and the number of grooves was reduced, and a optical transmission tube (length 20 m) was produced as in the case of Application Example 1.

[0030] [Comparative Example 1] An FEP tube (inner diameter 12 mm, outer diameter 13 mm) having an Ra in the light travel direction and peripheral direction of 0.03 mm and a smooth inner surface was used as the cladding material, and an optical transmission tube (length 20 m) was produced as in Application Example 1.

[0031] [Comparative Example 2] An FEP tube (inner diameter 12 mm, outer diameter 13 mm) with an Ra in the light travel direction and peripheral direction of 0.6 mm and having a uniformly rough inner surface was used as the cladding material, and an optical transmission tube (length 10 m) was produced as in the case of Application Example 1.

[0032] [Comparative Example 3] An FEP tube (inner diameter 12 mm, outer diameter 13 mm) with an Ra in the light travel direction of 0.52 μm, and an Ra in the peripheral direction of 0.46 mm was used as the cladding material, and an optical transmission tube (length 10 m) was produced as in Application Example 1.

[0033] Light (metal halide lamp, 150 W) was transmitted from one end of the optical transmission tube produced above, and measurement of the luminance was performed at specific points. The results obtained are shown in Fig. 4 with straight lines A (Application Example 1), B (Application Example 2), C (Comparative Example 1), D (Comparative Example 2), and E (Comparative Example 3).

[0034] As shown in Fig. 2, an optical transmission tube with a high peripheral surface luminance can be produced, and the uniformity of the luminance is significantly improved in Application Example 1, and the luminance can be increased while uniformity of the luminance is retained when the number of grooves is reduced, in other words, when the value of Ra in the peripheral direction is reduced, in Application Example 2. On the other hand, the luminance at the peripheral surface is low since the inner surface of the cladding material is smooth in Comparative Example 1, and though very high peripheral surface luminance can be obtained in the region near the light source in Comparative Example 1 where a cladding material with an inner surface with uniform roughness, but a sharp decrease in the peripheral surface luminous can be observed as the distance from the light source increases. Furthermore, the uniformity of the peripheral surface luminance is reduced further in Comparative Example 3 where a cladding material having roughness in the peripheral direction than the case of Comparative Example 2.

[0035] [Application Example 3] In a flat optical transmission member having a transparent PMMA with a thickness of 5 mm for the core material and an air layer as cladding material, grooves with a depth of 5 μm and a width of 100 μm were produced at intervals of 5 mm at the boundary of the air layer in the light travel direction, and when measurements were made for the luminance as described above, a uniform luminance distribution in the travel direction was achieved.

[0036] According to the present invention, it is possible to produce an optical transmission member having a uniform, high surface luminance over the entire length while securing transmission of light that can be used safely even in an environment such as

underwater, etc.

[Brief description of figures]

[Fig. 1] A cross section view that shows an application example of the optical transmission member of the present invention.

[Fig. 2] A top view that shows an example of the fine roughness with projecting stripes and recessed grooves of the present invention.

[Fig. 3] A top view that shows a different example of the fine roughness with projecting stripes and recessed grooves of the present invention.

[Fig. 4] A graph that shows the relationship between the distance from the light source and luminance of the optical transmission members produced in the application examples of the present invention and the comparative examples.

[Explanation of codes]

1 Clad material

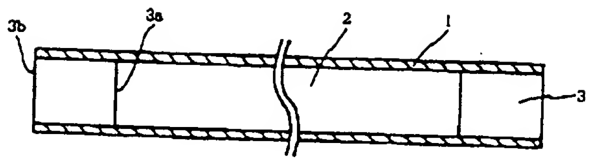
2 Core material

3 Stopper

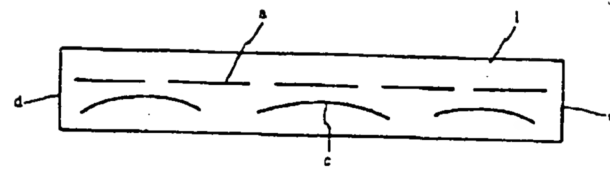
3a End face

3b End face

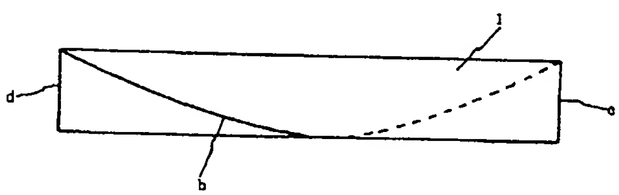
[Fig. 1]



[Fig. 2]



[Fig. 3]



[Fig. 4]

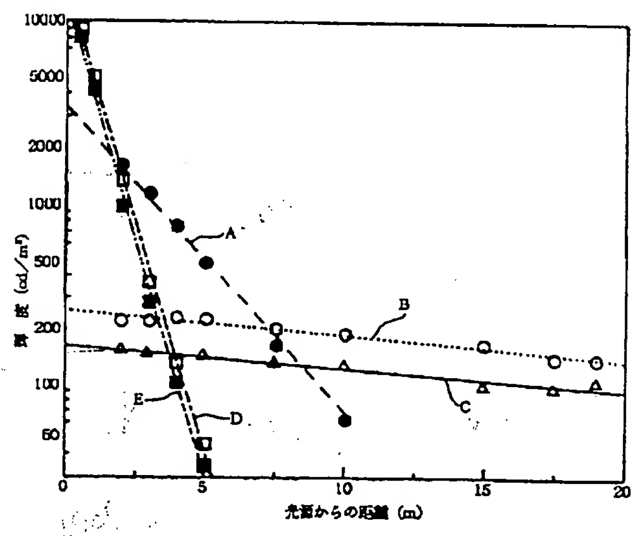


Fig. 4 legend:

Vertical axis: luminous (cd/m^2)

Horizontal axis: Distance from the light source (m)